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INTERNAL REPORT PM-R-73-14

THE EFFECT OF Cr, Co, AND Sr ADDITIONS ON THE DUCTILITY OF HYPEREUTECTIC Al-Si POWDER METALLURGY ALLOYS

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Nuclear and Powder Metallurgy Section

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H. M. Shelly* and C. F. Dixon**

ABSTRACT

The feasibility of improving the ductility of hypereutectic Al-Si powder metallurgy (P/M) alloys by additions of 0.2 to 1.0% Cr, Co, and Sr was investigated. Although no improvement in ductility was observed, increases in tensile strength (up to 20%) with no loss of ductility occurred in alloys containing Co or Sr.

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INTRODUCTION

Hypereutectic Al-Si alloys with a refined primary silicon phase and containing up to 45% Si have been produced in these laboratories using P/M techniques.[1] These alloys have good machinability, good wear resistance, low coefficient of thermal expansion, and their tensile strength is comparable to Al-Si cast material. However, their elongation, 2 to 3%, although better than that of the cast material, is still low and additions of Cu and Mg tend to reduce the ductility of these alloys.[1] In this investigation the effect of additions of 0.2, 0.5, and 1.0% Cr, Co, and Sr on the ductility of an Al-35% Si P/M alloy is examined.

EXPERIMENTAL PROCEDURE

The materials listed in Table 1 were used to prepare the pre-alloyed atomized powders listed in Table 2.

TABLE 1

ALLOY MATERIALS		
Material	Composition	Source
Aluminum	99.99%	Aluminum Co. of Canada Ltd.
Al-50% Si hardener	48.5% Si, 0.26% Fe	Kawecki Chemical Co.
Al-10% Cr hardener	9.1% Cr	Aluminum Co. of Canada Ltd.
Strontium	99.5%	Chromasco Corp.

TABLE 2

POWDER COMPOSITION (wt %)					
	Chemical Composition				
Nominal Composition	Si	Co	Sr	Cr	Fe
Al-35% Si - 0.2% Cr	36.12			0.20	0.11
Al-35% Si - 0.5% Cr	35.51			0.47	0.08
Al-35% Si - 1.0% Cr	36.55			0.94	0.06
Al-35% Si - 0.2% Co	34.76	0.17			0.09
Al-35% Si - 0.5% Co	35.68	0.44			0.09
Al-35% Si - 1.0% Co	34.22	0.90			0.08
Al-35% Si - 0.2% Sr	35.86		0.14		0.09
Al-35% Si - 0.5% Sr	35.46		0.37		0.08
Al-35% Si - 1.0% Sr	33.54		0.89		0.09

Alloy melts were prepared in a resistance furnace by conventional methods then poured into an apparatus in which a stream of molten metal was atomized by jets of compressed air. The powders were collected in a water bath, dried, and screened.

The minus 149 μm (100-mesh) fraction of the powders was isostatically cold pressed for 5 min at 6.9MN/m^2 (10,000 psi) then unidirectionally hot pressed at 550°C (1020°F) and 26.2 MN/m^2 (38,000 psi) for 5 min into billets 3.2 cm in diameter by 3.8 cm long. Density of these billets was about 96% theoretical.

Hot-pressed billets containing Cr were solution heat treated for 1/2 hr at 550°C (1020°F) then water quenched. These billets were chosen as the ones most likely to respond to heat treatment.

Tensile specimens 3.8 cm long with a gauge length of 1.6 cm and a gauge diameter of 0.4 cm were machined from hot-pressed as well as hot-pressed

and heat-treated billets. Tests were done in air at room temperature on an Instron machine.

Microexamination was carried out on all tensile specimens.

Samples for chemical analysis were taken from the minus 149 μm (100-mesh) powder.

RESULTS AND DISCUSSION

Chemical analysis results in Table 2 show that the silicon content of the experimental alloys varies between 33.54 and 36.55% and that the Cr, Co, and Sr contents are on the low side. These compositions, although off nominal, were considered satisfactory for the purpose of this investigation. The 0.06 to 0.11% Fe originated in the 0.26% Fe in the Al-50% Si hardener (Table 1).

Microexamination of the alloys showed that the Cr, Co, and Sr had no visible effect on the microstructure. Figure 1 is a photomicrograph showing the microstructure of the Al-35% Si-1% Co alloy, which is typical of all the other alloys. This microstructure can be compared with that of an Al-35% Si alloy previously examined [2] and shown in Figure 2.

The mechanical properties of the alloys are listed in Table 3.

TABLE 3

MECHANICAL PROPERTIES					
Alloy (Nominal Composition)	Condition	UTS MN/m^2 (ksi)	0.2% Y.S. MN/m^2 (ksi)	% El $4\sqrt{area}$	VHN 5kg Load
Al-35% Si - 0.2% Cr	Hot Pressed	19.9 (28.9)	17.7 (25.7)	1	91
Al-35% Si - 0.5% Cr	Hot Pressed	21.0 (30.4)	18.1 (26.3)	1.5	98
Al-35% Si - 1.0% Cr	Hot Pressed	22.5 (32.6)	19.7 (28.5)	0.5	105
Al-35% Si - 0.2% Cr	Heat Treated	22.7 (32.9)	20.5 (29.8)	1	102
Al-35% Si - 0.5% Cr	Heat Treated	22.8 (33.0)	20.4 (29.6)	0.5	107
Al-35% Si - 1.0% Cr	Heat Treated	25.7 (37.3)	23.0 (33.4)	1	121
Al-35% Si - 0.2% Co	Hot Pressed	19.2 (27.8)	17.1 (24.8)	2	87
Al-35% Si - 0.5% Co	Hot Pressed	18.5 (26.8)	17.4 (25.3)	2.5	92
Al-35% Si - 1.0% Co	Hot Pressed	20.3 (29.4)	18.7 (27.1)	3	101
Al-35% Si - 0.2% Sr	Hot Pressed	19.6 (28.4)	18.0 (26.1)	2	94
Al-35% Si - 0.5% Sr	Hot Pressed	20.1 (29.1)	18.6 (27.0)	2	93
Al-35% Si - 1.0% Sr	Hot Pressed	20.6 (29.9)	19.9 (28.9)	2	91
Al-35% Si*	Hot Pressed	17.2 (24.9)	16.1 (23.4)	2 to 3	85
Al-22 to 25% Si**	Heat Treated	18 to 21 (26 to 31)	-	0.1 to 0.3	98 to 135

* Previously Investigated P/M Alloy[1]

** Cast Piston Alloys[3]

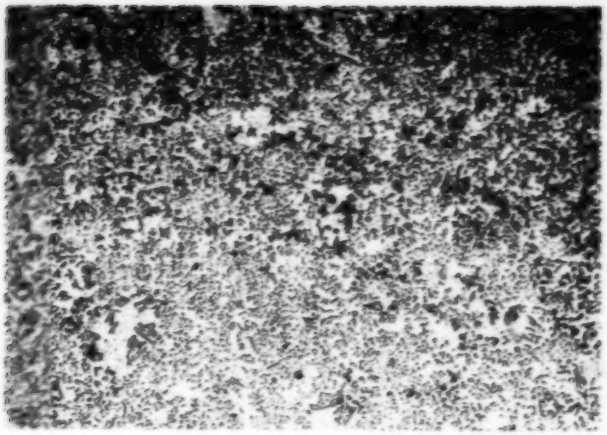

Figure 1. Al-35% Si - 1% Co
100X

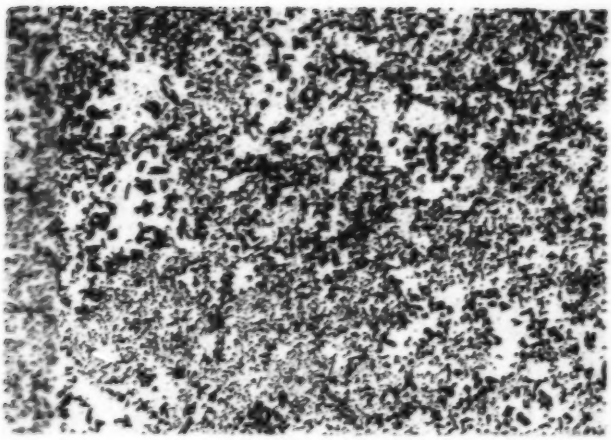

Figure 2. Al-35% Si
100X

Included for comparison purposes are values for an Al-35% Si hot-pressed alloy previously investigated and also values, obtained from the literature, for Al-Si cast alloys containing 22 to 25% Si[3]. These results show that additions of Cr, Co or Sr do not improve the elongation of the Al-35% Si P/M alloy. However, there are useful improvements in tensile strength, which increases from 17.2 MN/m^2 (24.9 ksi) for Al-35% Si to 25.7 MN/m^2) (37.3 ksi) for Al-35% Si-1% Cr heat treated and to 20.3 MN/m^2 (29.4 ksi) and 20.6 MN/m^2 (29.9 ksi) for the 1% Co and 1% Sr alloys, respectively.

CONCLUSIONS

Additions of 0.2 to 1% Cr, Co or Sr do not improve the ductility of an Al-35% Si P/M alloy, but they do result in useful improvements in tensile strength.

REFERENCES

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3. H. Kessler; Aluminum Piston Alloys in Germany; Light Metals, pages 85-88, March 1958.